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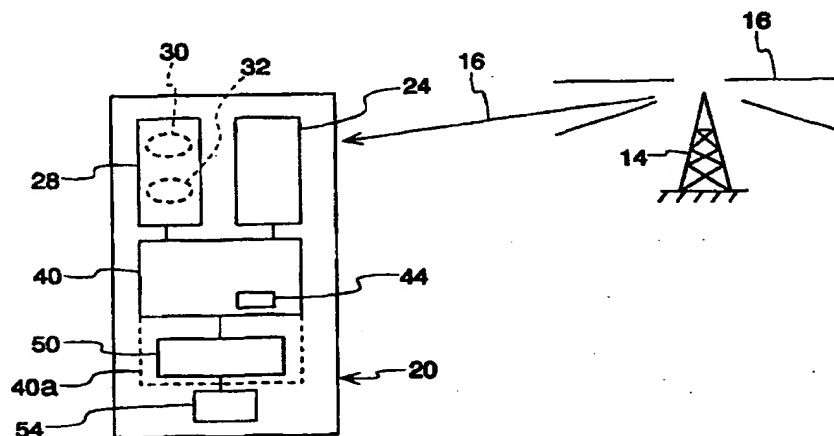
(57) Abstract

A mobile unit for communicating with a transmitter which transmits signals in data bursts, such data bursts having a plurality of symbols therein including data symbols and a plurality of predetermined pilot symbols. The symbols have a discrete number of possible values. The unit further includes a receiver adapted to receive a data burst of the transmitted signals, memory with the predetermined pilot symbols and a plurality of signals filters (interpolators), a comparator, a processor, and an output. The comparator compares the pilot symbols in a received data burst with the predetermined pilot symbols in the memory to determine correction factors for the pilot symbols. The processor uses the pilot symbol correction factors and the plurality of signal filters to derive a set of data symbol correction factors for each of the signal filters. The processor also adjusts discrete possible values of the data symbols by the data symbol correction factors and compares those adjusted values with the received data symbols to determine a cumulative error value among adjusted data symbols for each signal filter. The processor uses the data symbols derived by the signal filter having the lowest cumulative error value to demodulate a received data burst.

METHOD FOR IMPROVING SIGNAL RECEPTION IN A MOBILE COMMUNICATION UNIT BY USING PILOT SYMBOLS

RELATED APPLICATION

Priority is claimed in U.S. Provisional Application No. 60/085,769, entitled "Mobile Unit for Pilot Symbol Assisted Wireless System and Method of Improving Performance Thereof", Ayman Mostafa and Rajaram Ramesh, filed May 15, 1998.

BACKGROUND OF THE INVENTION

TECHNICAL FIELD

The present invention is directed toward communication systems, and more particularly toward pilot symbol assisted wireless systems.

BACKGROUND ART

Signals for wireless systems are subjected to varying conditions which can degrade the signal received by the mobile units using the system.

For example, a mobile unit can receive the signal from multiple directions (e.g., directly from the base unit, and reflected off of many different ground objects), with the varying signal sources potentially being out of phase and thereby tending to cancel each other out to some degree, reducing signal strength. Such signal fading, generally known as Rayleigh fading, occurs spatially over the area of the system, with specific areas potentially having significant fading which could cause the mobile unit to lose the signal entirely.

Still further, mobile units are subject to the Doppler effect as they move about the system. As is known in the art, whenever relative motion exists between the signal source/transmitter and signal recipient/receiver, there is a Doppler shift of the frequency components of the received signal. Thus, where the recipient is in a vehicle moving at a speed v, the maximum Doppler shift frequency f_d (occurring when the vehicle is moving directly at or directly away from the signal source) is:

$$f_d = v/\lambda$$

Component waves arriving from ahead of the vehicle experience a positive Doppler shift (*i.e.*, the frequency increases) while those arriving from behind the vehicle have a negative shift (*i.e.*, the frequency decreases). Thus, if a vehicle

5 is traveling 60 km/hr, at 900 MHz (λ ~ 0.33 m) the maximum Doppler shift (when the vehicle is traveling directly toward or away from the signal source) is:

$$f_d = [60,000 \text{ m/hr/3600 sec/hr}]/0.33 \text{ m} = 50 \text{ Hz}$$

Of course, a proportional change in frequency, or speed, would produce a proportional change in f_d. This shift in frequency results in the maximum signal

10 strength being at the shifted frequency rather than the assigned frequency, with the signal strength being significantly less at the assigned frequency (as perceived by the moving mobile unit) which is demodulated by the mobile unit. If the mobile unit happens to also pass through an area in the system subjected to significant Rayleigh fading, a significant loss in signal strength can accordingly

15 result.

In any event, the net result of these and other factors is that the signal which is transmitted by the transmitter (*e.g.*, a cell tower) will be distorted by the time it reaches the receiver (*e.g.*, cellular telephone). In a cellular telephone, for example, this can result in distortion objectionable to the ear, or

20 even a lost signal.

In order to account for this distortion, channel estimates have been used to determine the signal distortion at known pilot symbols in the data bursts and correction factors at other symbols in the data bursts have been interpolated based on the channel estimates at the pilot symbols. As an example, data

25 bursts have been transmitted in the IS-136 System with 162 symbols, each symbol comprising two bits. In a proposed extension of the IS-136 System, the data bursts of 162 symbols at predetermined, known locations P_i in the data bursts are predetermined, known pilot symbols S_{Pi} (where i = 1 to n, n being the number of pilot symbols used). In the proposed extension of the IS-136 Sys-

30 tem, each symbol contains three bits.

As also described further below, the correction factors (*i.e.*, channel estimates) derived from the pilot symbols can be used to estimate the most likely value for each data symbol in a data burst. That is, the channel estimates derived from the pilot symbols may be interpolated to determine the correction factors at the other symbols (*i.e.*, data symbols) in the data burst by using an interpolator or filter selected to best work under the conditions most likely to be encountered by the communication unit. In order to provide acceptable performance, such interpolator or filter essentially needs to be designed so as to handle the highest possible vehicle speed. For example, an interpolator or filter designed to accommodate a Doppler effect encountered at 60 kph will not provide acceptable performance for a vehicle traveling at 70 kph toward or away from the cell tower). Unfortunately, this has unavoidably resulted in required use of an interpolator or filter which causes degradation in the estimation of symbols which are received under conditions other than those parameters upon which the interpolator or filter is designed (*e.g.*, degradation at a low vehicle speed). This degradation can be even worse in areas where very high vehicle speeds must be anticipated since the interpolator must be designed based on very high anticipated speeds which oftentimes will not be encountered.

The present invention is directed toward overcoming one or more of the problems set forth above.

SUMMARY OF THE INVENTION

In one aspect of the present invention, a mobile communication unit which is subjected to conditions which degrade the receipt of a signal is provided. The unit includes a receiver adapted to receive a signal having multiple symbols therein including predetermined pilot symbols, a processor adapted to demodulate received symbols based on an interpolator using the error in the received pilot symbols, and an output adapted to receive symbols demodulated using the interpolator which is best adapted to correctly demodulate selected ones of the received symbols under the conditions to which the communication

unit is subjected when the symbols being demodulated are received. The processor selects that interpolator from at least two possible interpolators which is best adapted to correctly demodulate the received symbols under the conditions to which the communication unit is subjected when the symbols being demodu-
5   lated are received.

In a preferred form of this aspect of the present invention, the received signals include error detection coding and an error detection decoder decodes the signal using the at least two interpolators with the processor selecting that interpolator which the decoder detects as having the least errors as the
10   best adapted interpolator.

In another preferred form of this aspect of the present invention, the selected ones of the received symbols comprise less than half of the received symbols and, in one preferred form, the selected ones of the received symbols are from more than one data burst in the signal.

15   In still another preferred form of this aspect of the present invention, the mobile communication unit also includes memory maintaining at least two interpolators. In one alternate, the processor of this preferred form demodulates the selected ones of the received symbols using all of the at least two interpolators and selects that interpolator which has the least cumulative error
20   in the demodulated symbols from discrete possible values of the symbols as the one best adapted to correctly demodulate the received symbols. In another alternate of this preferred form of this aspect of the present invention, the communication unit includes an estimator for determining the conditions to which the communication unit is subjected when the symbols that need to be
25   demodulated are received, and the memory also stores information regarding the conditions under which each of the at least two interpolators is best adapted to correctly demodulate the received symbols. In a preferred form of this other alternate, the estimator is an algorithm estimating the Doppler shift of the unit, and the information in the memory is the range of Doppler shifts at which each

of the at least two interpolators is best adapted to correctly demodulate the received symbols.

In another preferred form of this aspect of the present invention, the mobile communication unit includes memory storing a first algorithm for deriving any of a plurality of interpolators based on selected conditions to which the communication unit is subjected when symbols being demodulated are received, and also includes a sensor for determining the selected conditions to which the communication unit is subjected when the symbols being demodulated are received, with the processor using the selected conditions determined by the sensor to derive an interpolator from the algorithm. In a preferred form, one selected condition determined by the sensor is the Doppler shift and the first algorithm stored by the memory derives interpolators based on Doppler shift. In another preferred form, the sensor is a second algorithm for determining the Doppler shift and the first algorithm stored by the memory derives interpolators based on Doppler shift.

In another aspect of the present invention, a mobile unit is provided for communicating with a transmitter which transmits signals in data bursts, such data bursts having a plurality of symbols therein including data symbols and a plurality of predetermined pilot symbols. The symbols have a discrete number of possible values. The unit further includes a receiver adapted to receive a data burst of the transmitted signals, memory with the predetermined pilot symbols and a plurality of signal filters, a comparator, a processor, and an output. The comparator is adapted to compare the pilot symbols in a received data burst with the predetermined pilot symbols in the memory to determine channel estimates at the locations of the pilot symbols. The processor is adapted to use the pilot symbol channel estimates and the plurality of signal filters to derive a set of data symbol correction factors for each of the signal filters. The processor is adapted to adjust the discrete possible values of the data symbols by the data symbol correction factors and compare the adjusted data symbols with selected received data symbols to determine a cumulative

error value among the selected received data symbols for each signal filter. The output is adapted to receive symbols demodulated by the processor using the interpolator having the lowest cumulative error value.

In a preferred form of this aspect of the present invention, the

5   processor is adapted to measure an error as the difference between a selected received data symbol and the closest adjusted discrete possible value of the data symbols, and the cumulative error value for each signal filter is the sum of the squares of the absolute values of the error at each selected received data symbol.

10   In another preferred form of this aspect of the present invention, the cumulative error value is determined from selected received data symbols from more than one data burst.

In still another aspect of the present invention, a mobile unit is provided for communicating with a transmitter which transmits signals. The

15   unit includes a receiver adapted to receive the transmitted signals, memory with a plurality of signal filters, the signal filters being selected to correct for selected Doppler shifts, an estimator estimating Doppler shift of the unit, and a demodulator responsive to the estimator for demodulating the transmitted signal as received by the receiver using the selected one of the signal filters which best

20   corrects for the estimated Doppler shift.

In a preferred form of this aspect of the present invention, the estimator is an algorithm for estimating the Doppler shift of the unit.

In another preferred form of this aspect of the present invention, the estimator is a processor which for each signal filter compares selected

25   symbols in the received signal with discrete possible values of the symbols adjusted by the each filter to determine an error figure for each signal filter, the estimated Doppler shift falling in a range of Doppler shifts best corrected by the signal filter having the smallest determined error figure.

In yet another aspect of the present invention, a method is provided

30   for improving the signal reception of a mobile communication unit, including the

steps of (a) transmitting a signal from a base station with data symbols having discrete possible values and pilot symbols with predetermined values at predetermined locations in the signal, (b) receiving the transmitted signal at the mobile communication unit, (c) deriving correction factors at the predetermined

5   locations of the pilot symbols in the signal by comparing the symbols as received by the mobile communication unit with the predetermined values of the pilot symbols, (d) using a plurality of interpolators to interpolate corrections for the data symbols based on the correction factors from step (c), (e) correcting the data symbols using the interpolated corrections from step (d) and comparing

10   the received data symbols to the adjusted discrete possible values for the data symbols to generate a cumulative error value for each interpolator, (f) selecting a set of data symbols which are the possible values closest to the corrected data symbols from the interpolator with the lowest cumulative error value, and (g) outputting the received signal using the selected data symbols.

15   In a preferred form of this aspect of the present invention, two interpolators are used in step (d), one interpolator being specially adapted to interpolate corrections for a communication unit traveling at high speeds and the other interpolator being specially adapted to interpolate corrections for a communication unit traveling at low speeds.

20   It is an object of the invention to provide mobile communication units such as cellular telephones which will provide maximum reliability and highest signal quality.

                      It is another object of the invention to provide mobile communication units which can demodulate high quality signals using current

25   transmission standards.

BRIEF DESCRIPTION OF THE DRAWINGS

                      Figure 1 is a schematic illustration of a data burst in a transmitted signal;

Figure 2 is a schematic illustration of a communication system including a mobile communication unit embodying the present invention;

Figure 3 is a schematic illustration of a mobile communication unit embodying an alternate embodiment of the present invention; and

Figure 4 is a schematic illustration of a mobile communication unit embodying another alternate embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiments of the present invention are illustrated in the Figures.

In the data burst 10 illustrated in Fig. 1, five pilot symbols S_{P1}, S_{P2}, S_{P3}, S_{P4}, S_{P5} are provided at positions P_1, P_2, P_3, P_4 and P_5. Of course, more or less than five pilot symbols could also be used in a data burst. At each pilot position P_i, the pilot symbols S_{Pi} may be one or more symbol. As an example, in the extensions of the IS-136 System, the number of symbols at positions P_1, P_2, P_3, P_4 and P_5 are 14. 3, 3, 3, and 3 respectively.

As illustrated in Fig. 2, a base station transmitter 14 transmits signals 16 which include data bursts 10 to receivers (for example, a mobile communication unit 20 such as a cellular telephone) at a selected frequency within a bandwidth appropriated for signals between the transmitter 14 and mobile communication unit 20.

In the prior art, the pilot symbols S_{Pi} (where i is 1 to 5 in the Fig. 1 example) are used to correct for variations in channel conditions along the data burst 10. That is, known pilot symbols S_{Pi} are provided at known positions within the data burst 10. The communication unit 20 compares the received symbol R_{Pi} which it receives at those known positions P_i with the known symbols S_{Pi} and determines an appropriate factor C_{Pi} for each position P_i to correct for that signal degradation. For example, if the symbol at P_i is known to have been transmitted as S_{Pi}, and the communication unit actually receives R_i at P_i, C_{Pi} may be determined during synchronization so that:

$$\sum |R_{Pi} - C_{Pi} * S_{Pi}|^2$$

is minimized. The C_{Pi} determined for the selected positions P_i along the data burst are then used to determine appropriate C_{Pi} for all symbol positions along the data burst 10 by suitable interpolation.

5   Simple linear interpolation is schematically illustrated in Fig. 1. However, interpolation to determine appropriate correction factors C_i for all data symbols S_i between the pilot symbols S_{Pi} is preferably done by use of an appropriate interpolator or Weiner filter such as is known in the art, and as explained in "Designs for Pilot-Symbol-Assisted Burst-Mode Communications

10   with Fading and Frequency Uncertainty", by Wen-yi Kuo and Michael P. Fitz, *International Journal of Wireless Information Networks*, Vol. 1, No. 4, 1994, pp. 239-252, the complete disclosure of which is hereby fully incorporated by reference.

          The interpolated C_i at each symbol position along the data burst 10

15   is then used to demodulate the symbols in the burst 10. For example, at symbol 20 in the data burst, a factor C_{20} is interpolated as discussed above. The proper symbol is then determined by calculating which signal S_{20J} results in the least "metric" or error factor m_{20} at position 20 according to the following:

$$m_{20} = |R_{20} - C_{20} * S_{20J}|^2, \text{ where:}$$

20   R_{20} is the symbol received at position 20; and

          S_{20J} are the hypothetical possible symbols at position 20 (where, for example, there are four possible discrete values for symbols [*i.e.*, four possible waveforms, J being 1 to 4] when modulation is QPSK [Quadrature Phase Shift Keying] and there are eight possible

25   symbols [*i.e.*, J is 1 to 8] when modulation is 8-PSK [8 Phase Shift Keying]).

According to one manner of prior art channel estimating, whichever of the discrete J number of symbols S_{20J} gives the lowest m_{20} is used as the most likely symbol for position 20, which symbol is used in demodulating the data

30   burst 10.

In the preferred embodiment, the present invention also uses C_{Pi} as determined at the positions P_i of the pilot symbols and as interpolated therebetween (C_i at each symbol position). However, it should be understood that the present invention could be used with different methods of determining C_{Pi} at the pilot symbol positions P_i and interpolating C_i for the data symbols, and should not be limited to the methods of determining C_{Pi}, C_i described herein for illustration purposes.

Most simply put, in accordance with the preferred embodiment of the present invention, the communication unit 20 includes a receiver 24 and memory 28 which stores not only the information regarding the pilot symbols S_{Pi} but also stores multiple filters or interpolators 30, 32, such as Weiner filters. The mobile communication unit 10 also includes a suitable processor 40 for interpolating C_i based on the symbols R_{Pi} received at the pilot positions P_i using each of the Weiner filters or other interpolators 30, 32 stored in the unit memory 28 as described further below. A comparator 44, which may be a part of the processor 40, compares the results of the processed data bursts 10 (as described below) to select the symbols to demodulate to provide the best signal quality in the unit 20.

The processor 40 further uses these correction factors C_i to estimate the most likely value (of the discrete possible values) for each symbol, and also generates a "metric" or error factor m_i such as previously described for each symbol S_i in the data burst 10. These error factors are summed to generate a cumulative error value for each filter according to the following:

$$M_F = \sum_{i=1}^{N} m_{Fi}, \text{ where}$$

M_F is the cumulative error value for filter F; and

m_{Fi} is the error factor at symbol S_i for filter F, where there are N symbols, where, in accord with the previous discussion:

$$m_{Fi} = |R_i - C_{Fi} * S_{iJ}|^2, \text{ where:}$$

R_i is the symbol received at position i; and

S$_{i,j}$ are the hypothetical possible symbols at position i, there being J possible discrete values for such symbols.

The comparator 44 compares those cumulative errors to essentially determine which cumulative error value M$_F$ is lowest. The filter 30 or 32 having the lowest cumulative error value M$_F$ is used to determine the appropriate symbols S$_i$ in the data burst 10, and those symbols are demodulated by a demodulator 50 to provide a high quality output signal at the output 54 such as a speaker in the communication unit 20 (the demodulator 50 may be separate as shown in the Figures, or may be a part of the processor 40, with the processor 40 doing the demodulation, as indicated by the dashed lines 40a in Figs. 2-4). The calculation of the cumulative metric can be done at the locations of all data symbols in the slot or, preferably, only a subset of data positions in the data burst or slot (for example, at about 20 data positions).

In an alternative embodiment, the receiver accumulates the cumulative error across multiple slots and chooses the interpolator based on this accumulated value.

The data symbols are typically protected by some combination of error correction coding and error detection coding. In an alternative embodiment, the demodulated symbols obtained using the multiple interpolators are passed to the error detection decoder and the symbols with the least detected errors (of one slot or multiple slots) lead to the choice of the interpolation filter.

As another alternative embodiment shown in Fig. 3, rather than test each filter 30, 32 for a cumulative error value in accord with the above described preferred embodiment, the filters 30, 32 could be stored with information 30a, 32a that one filter 30 is best suited for use in certain conditions of the communication unit (e.g., low vehicle speeds) and the other filter 32 is best suited for use in other conditions (e.g., high vehicle speeds), and the unit 20 also includes a suitable sensor 60 for determining such conditions. Specifically, filters may be stored which are best suited for different ranges of

Doppler shift, and the sensor 60 may be of a type which senses or estimates Doppler shift in the unit 20'. Manners of estimating Doppler shift such as may be used with the sensor 60 of this embodiment are shown in U.S. Patent Nos. 4,723,303 and 5,016,017 and Taiwan Patent 59862, the complete disclosures

5 of which are hereby fully incorporated by reference.

Yet another alternative to the Fig. 3 embodiment is illustrated in Fig. 4, in which a suitable algorithm 64 for developing an appropriate filter 30 is stored in the memory 28 of the unit 20" based on selected variables indicative of the condition of the unit 20" and which can be determined or estimated, such

10 as Doppler shift. Such algorithms are known to those skilled in the art for developing, for example, Weiner filters, and exemplary algorithms are disclosed in "Designs for Pilot-Symbol-Assisted Burst-Mode Communications with Fading and Frequency Uncertainty", by Wen-yi Kuo and Michael P. Fitz, *International Journal of Wireless Information Networks*, Vol. 1, No. 4, 1994, pp. 239-252,

15 the complete disclosure of which is hereby fully incorporated by reference. While such algorithms can require significant memory and processing speeds, such requirements are somewhat offset by eliminating the needs to store multiple filters and by also eliminating the need to process the signal multiple times (since, with this alternate, a single filter may be generated and used based

20 on the unit conditions, as opposed to testing/comparing the signal against multiple filters as occurs with the above described preferred embodiment). Of course, as processing speeds and memory costs increase with technology, any drawbacks resulting from such requirements may be effectively eliminated.

Still other aspects, objects, and advantages of the present invention

25 can be obtained from a study of the specification, the drawings, and the appended claims. It should be understood, however, that the present invention could be used in alternate forms where less than all of the objects and advantages of the present invention and preferred embodiment as described above would be obtained.

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CLAIMS

1.   A mobile communication unit subjected to conditions which
degrade the receipt of a signal, comprising:
        a receiver adapted to receive a signal having multiple symbols therein
including predetermined pilot symbols;
        a processor adapted to demodulate all received symbols based on an
        interpolator using the error in the received pilot symbols, said
        processor selecting that interpolator from at least two possible
        interpolators which is best adapted to correctly demodulate
        selected ones of the received symbols under the conditions to
        which the communication unit is subjected when the symbols
        being demodulated are received; and
an output adapted to receive symbols demodulated by the processor
        using the interpolator which is best adapted to correctly demo-
        dulate the selected ones of the received symbols under the
        conditions to which the communication unit is subjected when the
        symbols being demodulated are received.

2.   The mobile communication unit of claim 1, wherein said
signal includes error detection coding and further comprising an error detection
decoder, said error detection decoder decoding the signal using said at least two
interpolators and said processor selecting that interpolator which said decoder
detects as having the least errors as said best adapted interpolator.

3.   The mobile communication unit of claim 1, wherein said
selected ones of the received symbols comprise less than half of said received
symbols.

4.   The mobile communication unit of claim 3, wherein said

2   selected ones of the received symbols are from more than one data burst in said

signal.

5.   The mobile communication unit of claim 1, further

2   comprising memory maintaining said at least two interpolators.

6.   The mobile communication unit of claim 5, wherein:

2   said signals have a selected number of discrete possible values; and

said processor demodulates said selected ones of said received symbols

4   using all of said at least two interpolators and selects that

interpolator which has the least cumulative error in the

6   demodulated selected ones of said received symbols from said

discrete possible values as the one best adapted to correctly

8   demodulate all the received symbols under the conditions to which

the communication unit is subjected when the symbols being

10   demodulated are received.

7.   The mobile communication unit of claim 5, further

2   comprising an estimator for determining the conditions to which the

communication unit is subjected when the symbols being demodulated are

4   received, wherein said memory also stores information regarding the conditions

under which each of the at least two interpolators is best adapted to correctly

6   demodulate the received symbols.

8.   The mobile communication unit of claim 7, wherein said

2   estimator is an algorithm estimating the Doppler shift of the unit, and said

information in said memory is the range of Doppler shifts at which each of the

4   at least two interpolators is best adapted to correctly demodulate the received

symbols.

9. The mobile communication unit of claim 1, further comprising:

memory storing a first algorithm for deriving any of a plurality of interpolators based on selected conditions to which the communication unit is subjected when symbols being demodulated are received, and

a sensor for determining the selected conditions to which the communication unit is subjected when the symbols being demodulated are received, said processor using the selected conditions determined by the sensor to derive an interpolator from said algorithm.

10. The mobile communication unit of claim 9, wherein said selected conditions determined by said sensor is the Doppler shift and said first algorithm stored by said memory derives interpolators based on Doppler shift.

11. The mobile communication unit of claim 9, wherein said sensor is a second algorithm for determining the Doppler shift and said first algorithm stored by said memory derives interpolators based on Doppler shift.

12.   A mobile unit for communicating with a transmitter which
transmits signals in data bursts having a plurality of symbols therein including
data symbols and a plurality of predetermined pilot symbols, said symbols
having a discrete number of possible values, comprising:

a receiver adapted to receive a data burst of the transmitted signals;

memory with said predetermined pilot symbols and a plurality of signal
filters;

a comparator adapted to compare the pilot symbols in a received data
burst with the predetermined pilot symbols in the memory to
determine channel estimates for the pilot symbols;

a processor adapted to use said pilot symbol channel estimates and said
plurality of signal filters to derive a set of data symbol correction
factors for each of the signal filters, said processor also adapted to
adjust said discrete possible values of the data symbols by said
data symbol correction factors and compare said adjusted data
symbols with selected received data symbols to determine a
cumulative error value among the selected received data symbols
for each signal filter; and

an output adapted to receive symbols demodulated by the processor
using the interpolator having the lowest cumulative error value.

13.   The mobile unit of claim 12, wherein said processor is
adapted to measure an error as the difference between a selected received data
symbol and the closest adjusted discrete possible value of the data /symbols,
and said cumulative error value for each signal filter is the sum of the squares of
the absolute values of the error at each selected received data symbol.

14.   The mobile unit of claim 12, wherein said cumulative error
value is determined from selected received data symbols from more than one
data burst.

15. A mobile unit for communicating with a transmitter which

2   transmits signals, comprising:

a receiver adapted to receive the transmitted signals;

4   memory with a plurality of signal filters, said signal filters being selected

to correct for selected Doppler shifts;

6   an estimator estimating Doppler shift of said unit; and

a demodulator responsive to the estimator for demodulating the

8   transmitted signal as received by the receiver using the selected

one of the signal filters which best corrects for the estimated

10   Doppler shift.

16. The mobile unit of claim 15, wherein said estimator

2   comprises an algorithm for estimating the Doppler shift of said unit.

17. The mobile unit of claim 15, wherein said estimator

2   comprises a processor which for each signal filter compares selected symbols in

said received signal with discrete possible values of said symbols adjusted by

4   said each filter to determine an error figure for each signal filter, said estimated

Doppler shift falling in a range of Doppler shifts best corrected by the signal filter

6   having the smallest determined error figure.

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18.   A method for improving the signal reception of a mobile
communication unit, comprising the steps of:

(a)   transmitting a signal from a base station with data symbols having
discrete possible values and pilot symbols with predetermined values at
predetermined locations in the signal;

(b)   receiving the transmitted signal at the mobile communication unit;

(c)   deriving correction factors at the predetermined locations of the pilot
symbols in the signal by comparing the symbols as received by the mobile
communication unit with the predetermined values of the pilot symbols;

(d)   using a plurality of interpolators to interpolate corrections for said data
symbols based on the correction factors from step (c);

(e)   correcting said data symbols using the interpolated corrections from step
(d) and comparing said corrected data symbols to the discrete possible
values for said data symbols to generate a cumulative error value for each
interpolator;

(f)   selecting a set of data symbols which are the possible values closest to
the corrected data symbols from the interpolator with the lowest
cumulative error value; and

(g)   outputting the received signal using the selected set of data symbols.

19.   The method of claim 18, wherein two interpolators are used
in step (d), one interpolator being specially adapted to interpolate corrections for
a communication unit traveling at high speeds and the other interpolator being
specially adapted to interpolate corrections for a communication unit traveling at
low speeds.

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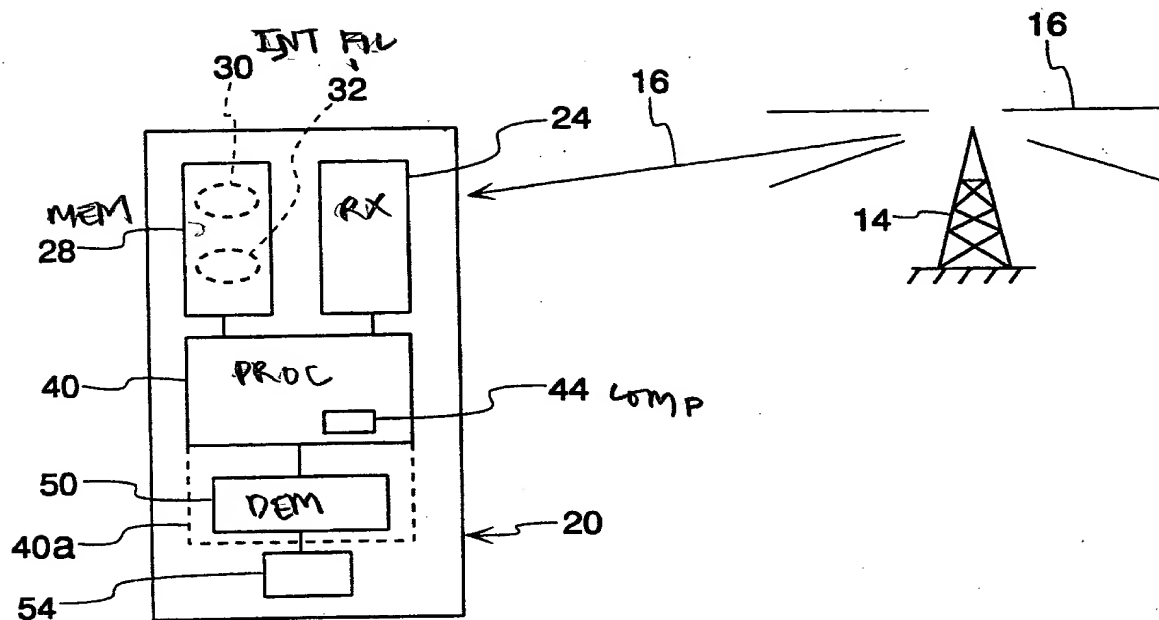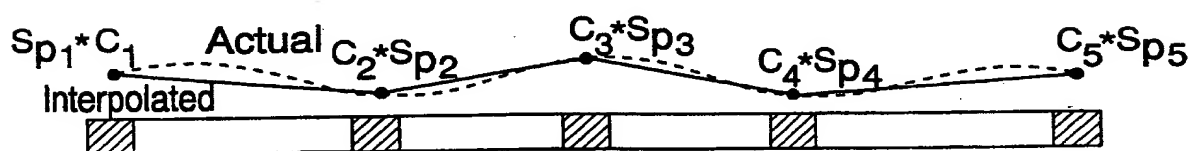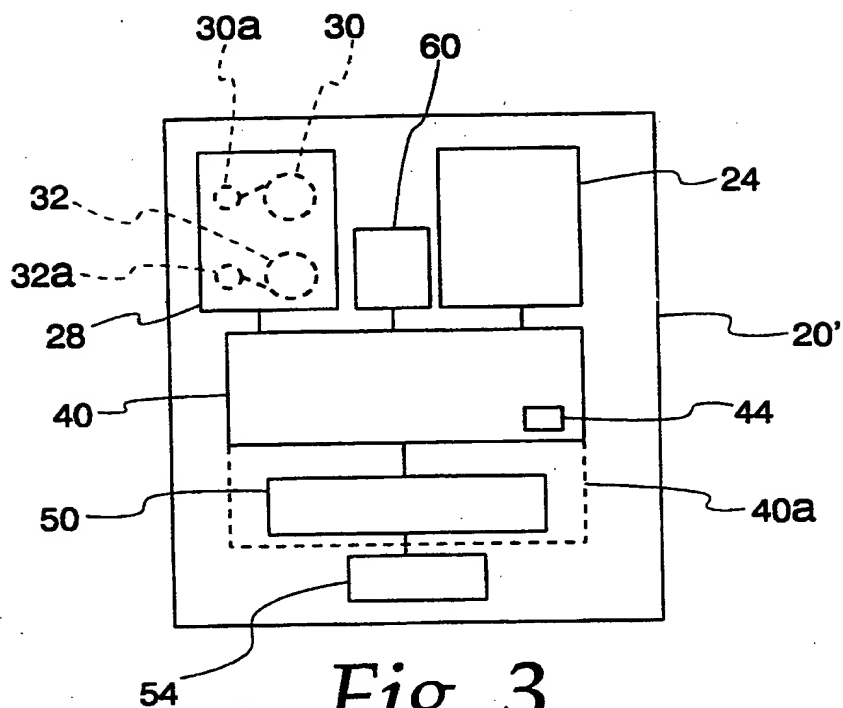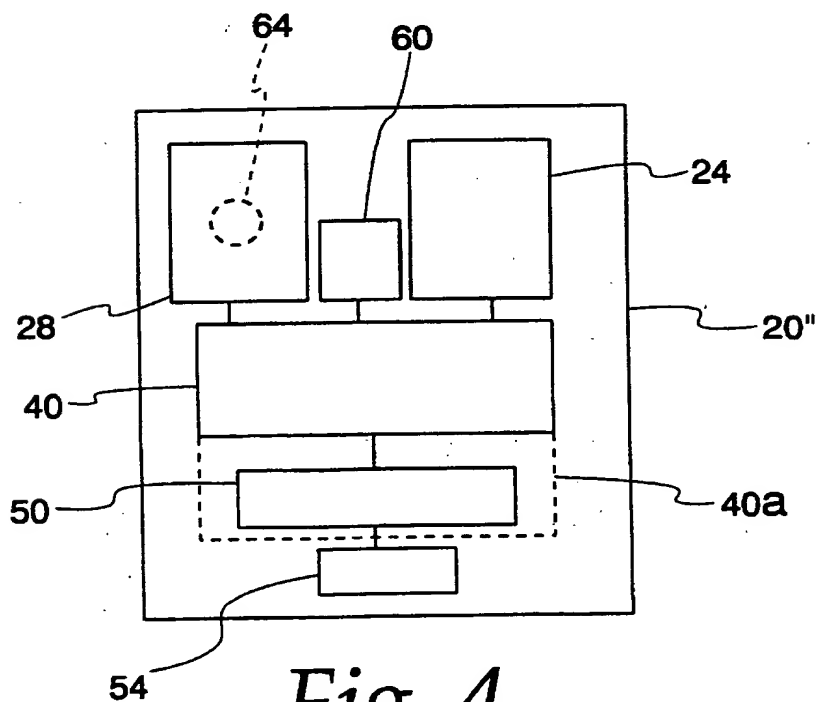*Fig. 2*

Fig. 1

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Fig. 3

Fig. 4

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INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   H04B7/005   H04L25/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   H04L   H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category°	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 605 955 A (GLENAYRE ELECTRONICS INC) 13 July 1994 (1994-07-13) abstract page 5, line 11 - line 15 page 7, line 53 - page 8, line 10 page 13, line 11 - line 40	1,3-5, 7-11
A		12-14, 18,19
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[X] Further documents are listed in the continuation of box C.　　[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
20 August 1999	03/09/1999

Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Koukourlis, S

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Int   ..Jonal Application No

PCT/US 99/09100

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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P,X	WO 99 08460 A (ERICSSON GE MOBILE INC) 18 February 1999 (1999-02-18) abstract page 3, line 9 - page 4, line 30 page 7, line 22 - line 29 page 8, line 13 - line 22 page 10, line 9 - page 11, line 12; figure 5 claims 1,7-9,21,31,43,55	1,3-5, 7-11,15, 16
A		12-14, 18,19
X	HENRY WAI-HUNG LI ET AL: "AN ADAPTIVE FILTERING TECHNIQUE FOR PILOT-AIDED TRANSMISSION SYSTEMS" IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, vol. 40, no. 3, 1 August 1991 (1991-08-01), pages 532-545, XP000266029 New York, USA ISSN: 0018-9545 abstract page 532, right-hand column, paragraph 2 page 534 - page 535, Section III-A	15-17
A		7-11,19
X	PATENT ABSTRACTS OF JAPAN vol. 095, no. 008, 29 September 1995 (1995-09-29) & JP 07 115373 A (NIPPON MOTOROLA LTD), 2 May 1995 (1995-05-02) abstract	15,16
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5 712 877 A (HO PAUL K M ET AL) 27 January 1998 (1998-01-27) abstract column 9, line 29 - line 35 figure 5 claims 1,10-12	1,12,18

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